DSP-based data recovery

Field of the Invention

The invention relates to the data acquisition in digital

5   storage media readout.

Background

10   Information readout from digital storage media with moving
parts always involves the task of recovering the bit clock
from the incoming time-continuous readout signal. Only with
a reliably known bit clock can the readout signal be
converted into a sequence of bits, and thus be ready for

15   subsequent time-discrete, fully digital processing.

Additionally, whenever a specific storage media format
foresees to group information into a repetitive pattern of
data frames of predefined layout, also denoted as sync

20   frames, the alignment of the data relative to this pattern
has to be recovered. This is also denoted as sync frame
alignment recovery. A related task, especially important
during random access, is to verify from the read data which
of the frames currently is being read, which is also

25   denoted as readout address recovery. Sync frame alignment
recovery and readout address recovery are made possible if
e.g. every sync frame begins with a dedicated sync pattern
and this sync pattern is additionally suffixed with an
address information. The sync pattern together with the

30   subsequent address information often is denoted as sync
code. For the example of the CD format, the sync pattern is
an 11T/11T signal, which is dedicated in so far as it
surpasses, for the mark as well as the space, the 10T
runlength limitation of pits containing ordinary data.

35   Similar approaches are used for other optical media
formats.

Additionally, whenever a storage media readout device is
compliant to more than one storage media types or formats,
the device has to recognize the media type at an early

5   stage after media insertion, in order to be able to perform
any subsequent data handling in accordance with the
specification(s) relevant for that specific type of media.

Problem to be solved:

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A known approach for bit clock recovery is a Phase-Locked
Loop (PLL); in case of digital optical media like Compact
Disk (CD), a digital PLL can be employed. Implementation of
a PLL always consumes power and silicon area; after media

15   insert, PLL-based signal recovery has to wait for the PLL
to be locked.

It is thus the aim of the present invention to provide a
method and apparatus which realize the required functions

20   of bit clock recovery, sync frame alignment recovery,
readout address recovery and media type recognition in a
way which avoids a PLL altogether.

An apparatus according to the present invention performs

25   one or more of the following functions:
- To recognize the type of media that is being accessed,
- To recover the bit clock during digital storage readout,
- To recover the sync frame alignment of the data,
- To decode, as early as possible, addressing information

30   contained in the data,
- To convert a readout signal to a bit sequence employing
the correct bit clock.

The invention is advantageously applicable in other fields
of digital technology like receiving digitally transmitted
signals.

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According to this invention, data recovery is performed
using the following steps in sequence:

a) A sequence of A-to-D-converted samples representing an
    oversampled readout signal from the storage medium is
10   stored in a memory.

b) The stored sample sequence is scanned for occurrences
    of one or more predefined sync patterns. The positions
    of found occurrences are memorised as sync positions.
    One way to realize this scanning is a cross-correlation
15   algorithm.

c) The distance between consecutive sync positions is
    measured.

d) From the distance of sync positions and the known sync
    frame structure, the base frequency of the samples is
20   calculated. From the sync positions and the base
    frequency, a bit clock is regenerated.

e) Using the regenerated bit clock, the sample sequence
    from memory is sample rate converted into a new
    sequence, which represents the readout signal when
25   sampled at the correct bit clock rate.

This has the general advantage that the power and area
consuming implementation of a sophisticated and complex
digital PLL is conceptually avoided.

30 Advantageously, data recovery according to this invention
    may additionally include the following step:

- Whenever an occurrence of a sync pattern has been found,
   the associated sync code is decoded by a pattern
   recognition algorithm.

This has the advantage that sync codes are detected and the
position of the read unit is determined at a very early
stage in signal processing. Any PLL locking is not
required. Hence the sync code decoding step proposed in the
5   invention is very fast, which is advantageous during random
access mode.

Also, advantageously, data recovery according to this
invention may additionally include the following step:
10   - From the distance between consecutive sync positions and
     the knowledge about which type of sync pattern has been
     found, recognize the format of the storage media (e.g.
     CD, DVD).
This has the advantage to constitute a very reliable media
15   recognition, because it is exclusively based on details of
the physical recording format that are fixed. It does not
rely upon storage media material properties, which may
vary. In case of optical disks, the reflectivity is known
to vary across media brands and even across manufacturing
20   lots; hence a media recognition based on reflectivity
measurement is error prone. Another advantage is that,
being located in very early stages of signal processing,
the described media recognition is considerably faster than
any methods based on evaluating disk reflectivity and/or
25   focus position.

The present invention provides the following advantages:
- The proposed algorithms to recover the data from a set of
  samples can easily be adapted, even during operation, to
30   the type of optical media, the applied channel modulation
  method and the actual drive speed. Therefore, it is
  possible to use different algorithms for each type of
  media in order to reduce the bit-error-rate of the read
  channel.

- It is even possible to first detect, using concepts of
  this invention, the type of media, and then to switch to
  one of a set of optimised algorithms of this invention
  for bit clock recovery and/or sync alignment.
5 - In this way, the invention offers improved flexibility in
  handling different media.

With other words, the invention describes a data recovery
method and apparatus for digital storage readout employing
10 sync frames, where an oversampled readout signal is stored
in memory, sync patterns are located in the signal using
DSP means, distances of consecutive sync pattern locations
are calculated, bit clock is recovered from these distances
and the knowledge about the data framing structure, and
15 data is converted to bit sequences which represent the
readout signal when sampled at the correct bit clock.

Brief description of the drawings
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     Fig. 1 shows in block diagram form the known approach for
            clock recovery.
     Fig. 2 shows in block diagram form an implementation of
            clock recovery and sample rate conversion according
25   to the invention.
     Fig. 3 shows the parallelisation approach for sample rate
            conversion.
     Fig. 4 shows in block diagram form the required
            enhancements to implement Sync ID decoding according
30   to the invention.

Exemplary embodiments

Bit clock recovery is one of the main problems for the
implementation of an acquisition path of digital storage
5   readout devices. Main target of the clock recovery is the
determination of the actual channel bit rate from a sampled
time-continuous read signal. This clock recovery has to
deal with a wide range of channel bit rates because of
different media (CD, DVD) and different read speeds. Today,
10   the channel bit rate varies from 4.12 Mbit/s (CD 1x) to 400
Mbit/s (DVD 16x). In the near future, 500 Mbit/s for DVD
20x have to be expected.
Most optical discs are recorded or pre-recorded with a
constant linear velocity (CLV) mode. This implies that for
15   a nominally constant channel bit rate, a higher rotational
speed is required when reading near the inner radius of the
data area, and a lower rotational speed at the outer
radius, and that rotational speed must be adapted whenever
the readout radius changes. Because rotation speed
20   adaptation is never perfect or instantaneous, momentary
channel bit rate will vary during read of the entire disc
and after jumps from one sector to another.

Fig. 1 shows the known approach for data recovery. This
25   approach is based on an Analog to Digital Converter 12, a
digital PLL 11, a Sample Rate Converter 13, and the Channel
Bit Decoding unit 14. The digital PLL 11 is used to derive
the actual channel bit rate and a phase information from
the samples of the analogue signal. Because this PLL has to
30   lock to a wide range of bit clock rates and various
different bit patterns with various different modulations
for CD and other optical media, the implementation of this
PLL is a very sophisticated and complex task. Main input
signal for the digital PLL is a phase information from the

channel bit decoding unit. The digital PLL·is locked if
this signal becomes zero.

The SRC 13 uses the signals from the digital PLL 11, namely
5   frequency and phase information, to convert the physical
samples into virtual ones, which correspond to the actual
channel bit rate.

Fig. 2 shows an implementation of clock recovery and sample
10   rate conversion according to the invention. First, a number
of n consecutive samples from the ADC 21 are stored in a
FIFO 22. Same as with the known approach described above,
the sample rate of the ADC 21 has to be at least equal to
the maximum channel bit rate, as taught by Shannon's
15   sampling theorem. The size of the FIFO 22 should be large
enough to store all samples between and including two
consecutive sync patterns.

In a side branch consisting of a Sync Pattern Detector 25
20   and a Channel Bit Rate Calulator 26, the actual channel bit
rate for this set of samples is determined by the
measurement of the distance between two consecutive sync
patterns. In one form or other, such sync patterns exists
for all optical storage media. Because the expected sample
25   sequence for the sync pattern is known in advance, the
required sync pattern detection 25 can be based on
algorithms like cross-correlation. From the distance
between consecutive sync patterns, channel bit rate
calculation 26 calculates the actual channel bit rate of
30   the samples stored in the FIFO 22. In a third step, the
samples are converted to the calculated channel bit rate by
the sample rate conversion unit 23, e.g. based on an
interpolation algorithm. Based on these converted samples,
Channel Bit Decoding 24 can then be performed.

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Fig. 3 shows a parallelisation approach for the sample rate
conversion. If implemented in an integrated circuit, this
advantageously results in highly parallel hardware
structures, such that high clock rates are avoided. The

5   samples from the ADC 301 are clocked into a number of FIFOs
302, 305, 308, 310 connected to the same number of SRC
units 303, 306, 309, 311. Because every SRC unit 303, 306,
309, 311 now has to handle only every n-th set of samples,
the throughput constraints are relaxed significantly. This

10 results in a lower clock speed for the SRC units. Because
the input FIFO processing speed is independent of the
sample rate of the ADC, the SRC units can be clocked
independently from the ADC. This is an advantage for high
speed drives, were clock rates up to 300 MHz for the ADC

15 are required. If channel bit rate calculation and sample
rate conversion are designed to handle 4 samples per clock,
the required clock speed for these units would be 75 MHz
only.

20 After the determination of the length of the sync codes
(measured in number of HF samples) and the distance of two
consecutive sync codes (also measured in number of HF
samples), the length of a channel bit in the HF signal is
also known in terms of HF samples.

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Fig. 4 shows the block diagram of a scheme for readout
address recovery. Same as in channel bit clock recovery, a
readout signal is digitised 41 and stored in a FIFO 42, and
the unique portions of the sync codes, namely the sync

30 patterns, are detected 45. Then, specifically, the
information from the sync pattern detection 45, mainly the
position information, is used for a simple decoding 47 of
the non-unique portion of the sync codes. This decoding is
based either on the HF signal (not shown) with the

35 advantage that this signal is available early in the

processing path, or on the resampled signal (48) with the
advantage that there, due to the resampling, the non-unique
portion of the sync codes is available in a temporally
standardised form which may contribute to simplify the
5   decoding task. Because only a limited set of valid sync
code exists for each format, a maximum likelihood decoder
may be applied.

In a favourable extension, media recognition, too, is
10 achieved based on cross correlation: First, the cross
correlator is programmed for the detection of a specific
type of sync codes. This is an 11T/11T signal for the
example of CD. The possible range of the length of the sync
codes is known from the current speed of the drive and the
15 assumed format. A search for sync codes is then performed,
e.g. an exhaustive search starting with the maximum
possible sync code length and stepwise refining the cross
correlator programming down to the minimal possible length.
Media recognition is considered successful as soon as
20 periodic sync codes are detected, i.e. as soon as a fixed
distance is found between any two consecutive sync codes.
If no periodic sync codes are detected throughout the
complete search, the media does not comply to the media
type of the sync code under investigation, the cross
25 correlator has to be reprogrammed for the detection of
another type of sync codes and the above described
procedure has to be repeated.